720.01 Impact Attenuator Systems

Impact attenuator systems are protective systems that prevent an errant vehicle from impacting a hazard by either gradually decelerating the vehicle to a stop when hit head-on or by redirecting it away from the hazard when struck on the side. These barriers are used for rigid objects or hazardous conditions that cannot be removed, relocated, or made breakaway.

Approved systems are shown on Figures 720-2a through 4b and on the Design Office web page at:

http://www.wsdot.wa.gov/EESC/Design/Policy/RoadsideSafety/Chapter720/Chapter720B.htm

(1) Permanent Installations

A description of each permanent installation system's purpose, parts, and function as well as requirements for; transition, foundation, and slope are provided as follows and in Figure 720-5:

(a) **Crash Cushion Attenuating Terminal (CAT)**

1. **Purpose**: The CAT is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.

2. **Description**: The system consists of slotted W-beam guardrail mounted on both sides of breakaway timber posts. Steel sleeves with soil plates hold the timber posts in place. See Figure 720-2a.

3. **Function**: When hit head-on, the slotted guardrail is forced over a pin that shears the steel between the slots. This shearing dissipates the energy of the impact.

4. **Foundation:** Concrete footings or foundations are not required.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(b) **Brakemaster**

1. **Purpose:** The Brakemaster system is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.

2. **Description:** The system contains an embedded anchor assembly, W-beam fender panels, transition strap, and diaphragm. See Figure 720-2a.

3. **Function:** The system uses a brake and cable device for head-on impacts and for redirection. The cable is embedded in a concrete anchor at the end of the system.

4. **Foundation:** A concrete foundation is not required for this system but a paved surface is recommended.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(c) **QuadTrend 350**

1. **Purpose:** The QuadTrend 350 is an end treatment for 32 in high concrete barriers. The system's short length allows it to be used at the ends of bridges where the installation of a beam guardrail transition and terminal is not feasible.

2. **Description:** This system consists of telescoping quadruple corrugated fender panels mounted on steel breakaway posts. See Figure 720-2a.

3. **Function:** Sand-filled boxes attached to the posts dissipate a portion of the energy of an impact. An anchored cable installed behind the fender panels directs the vehicle away from the barrier end.

4. **Foundation:** The system is installed on a concrete foundation to support the steel posts.

5. **Slope:** A 6H:1V or flatter slope is required behind the barrier to allow for vehicle recovery.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(d) TAU-II

1. **Purpose:** The TAU-II crash cushion system is an end treatment for concrete barrier and beam guardrail and is also used for narrow fixed objects.

2. **Description:** The system is made up of independent collapsible bays containing energy absorbing cartridges that are guided and supported during a head-on hit by high strength galvanized steel cables and thrie beam rail panels. Each bay is composed of overlapping thrie beam panels on the sides and structural support diaphragms on the ends. Structural support diaphragms are attached to two cables running longitudinally through the system and attached to foundations at each end of the system. See Figure 720-2c.

3. **Function:** Overlapping panels, structural support diaphragms, cable supports, cables, and foundation anchors allow the system to resist angled impacts and mitigate head-on impacts.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(e) QuadGuard, Wide QuadGuard

1. **Purpose:** The QuadGuard is an end treatment for concrete barrier and beam guardrail and is also used to mitigate fixed objects up to 7.5 ft wide.

2. **Description:** The system consists of a series of Hex-Foam cartridges surrounded by a framework of steel diaphragms and quadruple corrugated fender panels. See Figure 720-2b.

3. **Function:** The internal shearing of the cartridges and the crushing of the energy absorption material absorb impact energy from end-on hits. The fender panels redirect vehicles impacting the attenuator on the side.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the QuadGuard.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) QuadGuard Elite

1. **Purpose:** The QuadGuard Elite is an end treatment for concrete barrier and beam guardrail and is also used for fixed objects up to 7.5 ft wide.

2. **Description:** The system consists of telescoping quadruple corrugated fender panels mounted on both sides of a series of polyethylene cylinders. See Figure 720-2b.

3. **Function:** The cylinders are compressed during a head-on impact and will return to their original shape when the system is reset. The advantage of this system is that it can withstand numerous impacts without requiring extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the QuadGuard Elite.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(g) **Reusable Energy Absorbing Crash Terminal (REACT 350), Wide REACT 350**

1. **Purpose:** The REACT 350 is an end treatment for concrete barriers and is also used for fixed objects up to 9 ft wide.

2. **Description:** The system consists of polyethylene cylinders with varying wall thickness, redirecting cables, a steel frame base, and a backup structure. See Figure 720-2d.

3. **Function:** The redirecting cables are anchored in the concrete foundation at the front of the system and in the backup structure at the rear of the system. When hit head-on, the cylinders compress and absorb the impact energy, but the system returns to approximately 80% of its original length immediately. For side impacts, the cables restrain the system enough to prevent penetration and redirect the vehicle. It is anticipated that this system will require very few replacement parts or extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope**: If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the REACT 350.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(h) **Inertial Barrier**

Inertial barrier configurations are shown in the Standard Plans. If a situation is encountered where configurations in the Standard Plans are not appropriate, contact the Headquarters Design Office for further information.

1. **Purpose:** Inertial barrier is an end treatment for concrete barrier and to mitigate fixed objects. This system does not provide redirection from a side impact.

2. **Description:** This system consists of an array of plastic containers filled with varying weights of sand. See Figure 720-2d.

3. **Function:** The inertial barriers slow an impacting vehicle by the transfer of the momentum of the vehicle to the mass of the barrier. This system is not suitable where space is limited to less than the widths shown in the Standard Plans. Whenever possible, align inertial barriers so that an errant vehicle deviating from the roadway by 10 degrees would be on a parallel path with the attenuator alignment (See the Standard Plans). In addition, inertial barriers do not provide any redirection and are not appropriate where high angle impacts are likely.

4. **Foundation**: A paved surface is not required.

5. **Slope**: If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 5% for inertial barriers.

(2) Work Zone (Temporary) Installation

A description of each work zone (or other temporary) system's purpose, parts and functionality as well as requirements for; transition, foundation, and slope are provided as follows and in Figure 720-5:

(a) **ABSORB 350**

1. **Purpose:** The ABSORB 350 is an end treatment limited to temporary installations for both concrete barrier and the Quickchange Moveable Barrier (QMB).

2. **Description:** The system contains water filled Energy Absorbing Elements. Each element is 24 inches wide, 32 inches high, and 39 ½ inches long. See Figure 720-3.

3. **Function:** The low speed (below 45 mph) system uses 5 Energy Absorbing Elements and the high-speed (45 mph and above) system uses 8. The energy of an impact is dissipated as the elements are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(b) **Advanced Dynamic Impact Extension Module 350 (ADIEM 350)**

1. **Purpose:** The ADIEM 350 is an end treatment for concrete barrier. At this time, it is limited to temporary installations. Existing permanent installations are experimental and are being used to evaluate long-term durability. Existing permanent units may be reset.

2. **Description:** The system is 30 ft long and consists of 10 lightweight concrete modules on an inclined base. See Figure 720-3.

3. **Functionality:** An inclined base provides a track for placement of the modules and provides redirection for side impacts for roughly half the length. The energy of an impact is dissipated as the concrete modules are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the ADIEM 350.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(c) **QuadGuard cz**

This system is like the permanent QuadGuard listed for permanent systems above except that it can be installed on a 6 in minimum depth asphalt concrete surface that has a 6 in minimum depth compacted base. See Figure 720-2b.

(d) **Reusable Energy Absorbing Crash Terminal (REACT 350)**

This is the same system listed for permanent systems above except that it can be installed on a 4 in minimum depth asphalt concrete surface that has a 6 in minimum depth compacted base. See Figure 720-2d.

(e) **Non-Redirecting Energy Absorbing Terminal (N-E-A-T)**

1. **Purpose:** The N-E-A-T system is an end treatment for temporary concrete barrier where vehicle speeds are 45 mph or less.

2. **Description:** The N-E-A-T System's cartridge weighs about 300 pounds and measures 9.7 ft in length. The system consists of aluminum cells encased in an aluminum shell with steel backup, attachment hardware, and transition panels. It can be attached to the ends of New Jersey shaped portable concrete barrier and the moveable QuickChange Barrier. See Figure 720-3.

3. **Functionality:** The energy of an impact is dissipated as the aluminum cells are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) **Trinity Attenuating Crash Cushion (TRACC)**

1. **Purpose:** The TRACC is an end treatment for concrete barriers. It is limited to use in construction or other work zones on a temporary basis.

2. **Description:** The 21 foot long TRACC includes four major components: a pair of guidance tracks, an impact sled, intermediate steel frames, and 10 gauge W-beam fender panels. See Figure 720-3.

3. **Functionality:** The sled (impact face) is positioned over the upstream end of the guidance tracks and contains a hardened steel blade that cuts the metal plates on the sides of the guidance tracks as it is forced backwards when hit head-on.

4. **Foundation:** The system requires a concrete foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(g) **Inertial Barrier**

This is the same system listed for permanent systems above. It is not suitable where space is limited to less than the widths shown in the Standard Plans. See Figure 720-2d.

(h) **Truck Mounted Attenuator (TMA)**

TMAs are portable systems mounted on trucks. They are intended for use in work zones and for temporary hazards.

(3) Older Systems

The following systems are in use on Washington State highways and may be left in place or reset. New installations of these systems require approval from the Headquarters (HQ) Design Office.

(a) **Sentre**

The Sentre is a guardrail end treatment. Its overall length of 17 ft allowed it to be used where space was not available for a guardrail transition and terminal. The system is very similar to the QuadTrend-350 in both appearance and function except that it uses thrie beam fender panels instead of the quadruple corrugated panels. This system requires a transition when used to terminate rigid barriers. See Figure 720-4a.

(b) **TREND**

The TREND is an end treatment with a built-in transition and was used at the end of rigid barriers including bridge rails. The system is similar to the QuadTrend-350 except that it uses thrie beam fender panels. See Figure 720-4a.

(c) **G-R-E-A-T (Guard Rail Energy Absorption Terminal)**

This system was primarily used as an end treatment for concrete barrier. It is similar to the QuadGuard except that it uses thrie beam fender panels. See Figure 720-4a.

(d) **Low Maintenance Attenuator System (LMA)**

The LMA is an end treatment for concrete barrier and beam guardrail and was used for fixed objects up to 3 ft wide. The system is similar to the QuadGuard Elite except that it uses thrie beam fender panels and rubber cylinders. See Figure 720-4b.

(e) **Hex-Foam Sandwich**

The Hex-Foam Sandwich system is an end treatment for beam guardrail and concrete barrier and was also used for fixed objects 3 ft or more in width. This system consists of a number of Hex-Foam cartridges containing an energy absorption material separated by a series of diaphragms and restrained by anchor cables. It is installed on a concrete slab. Impact energy is absorbed by the internal shearing of the cartridges and crushing of the energy absorption material. The lapped panels on the perimeter serve to redirect vehicles for side impacts. If the site has grade or cross slope in excess of 5%, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. See Figure 720-4b.

720.02 Design Criteria

The following design criteria applies to all new or reset permanent and temporary impact attenuators. The design criteria also applies to existing systems to be left in place when the Barrier Terminals and Transition Sections columns on a design matrix applies to the project. (See Chapter 325.)

Impact attenuators must be placed so that they do not present a hazard to opposing traffic. For median and reversible lane locations, the backup structure or attenuator-to-object connection must be designed to prevent opposing traffic from being snagged. It is desirable that all existing curbing be removed and the surface smoothed with asphalt or cement concrete pavement before an impact attenuator is installed. However, curbs 4 in or less in height, may be retained depending on the practicality of their removal.

In general, attenuators are aligned parallel to the roadway except the inertial barriers.

720.03 Selection

When selecting an impact attenuator system, consider the following:

- Posted speed
- Available space (length and width)
- Maintenance costs
- Initial cost
- Duration (permanent or temporary use)

The posted speed is a consideration for the QuadGuard, REACT 350 (narrow model only), TAU II and the inertial barrier systems. Use Figure 720-1 to select permanent system sizes required for the various posted speeds.

Posted Speed (mph)	Quad Guard (Bays)	TAU-II (Bays)	REACT 350 (Cylinders)	Inertial Barrier (Type)
40 or less	3	4	4	1
45	4	8	6	2
50	5	8	6	3
55	6	8	9	4
60	6	8	9	5
65	8	8	9	6
70	9	8	11	6

Impact Attenuator Sizes
Figure 720-1

If it is anticipated that a large volume of traffic will be traveling at speeds greater than the posted speed limit, then the next larger unit may be specified.

See Figure 720-5 for a summary of space and initial cost information related to the impact attenuator systems.

When considering maintenance costs, anticipate the average annual impact rate. If few impacts are anticipated, lower cost devices such as inertial barriers might meet the need. Inertial barriers have the lowest initial cost and initial site preparation. However, maintenance will be costly and necessary after every impact. Labor and equipment are necessary to clean up the debris and install new containers (barrels). Also, inertial barriers must not be used where flying debris might be a danger to pedestrians.

The REACT 350 and the QuadGuard Elite have a higher initial cost, requiring substantial site preparation, including a backup or anchor wall in some cases and cable anchorage at the front of the installation. However, repair costs are comparatively low, with labor being the main expense. Maintenance might not be required after minor side impacts with these systems.

For new installations where at least one impact is anticipated per year, limit the selection of impact attenuators to the low maintenance devices (QuadGuard Elite and REACT 350). Consider upgrading existing ADIEM, G-R-E-A-T, and Hex-Foam impact attenuators with these low maintenance devices when the repair history shows one to two impacts per year over a three to five year period.

In selecting a system, one consideration that must not be overlooked is how dangerous it will be for the workers making repairs. In areas with a high exposure to danger, a system that can be repaired quickly is most desirable. Some systems require nearly total replacement or replacement of critical components (such as cartridges or braking mechanisms) after a head-on impact, while others only require resetting.

When specifying the system or systems that can be used at a specific location, the list shown in Figure 720-5 is to be used as a starting point. As the considerations discussed previously are analyzed, inappropriate systems may be identified and eliminated from further consideration. Systems that are not eliminated may be appropriate for the project. When the site conditions vary, it might be necessary to have more than one list of acceptable systems within a contract. Systems are not to be eliminated without documented reasons. Also, wording such as *or equivalent* is not to be used when specifying these systems. If only one system is found to be appropriate, then approval from the Assistant State Design Engineer of a public interest finding for the use of a sole source proprietary item is required.

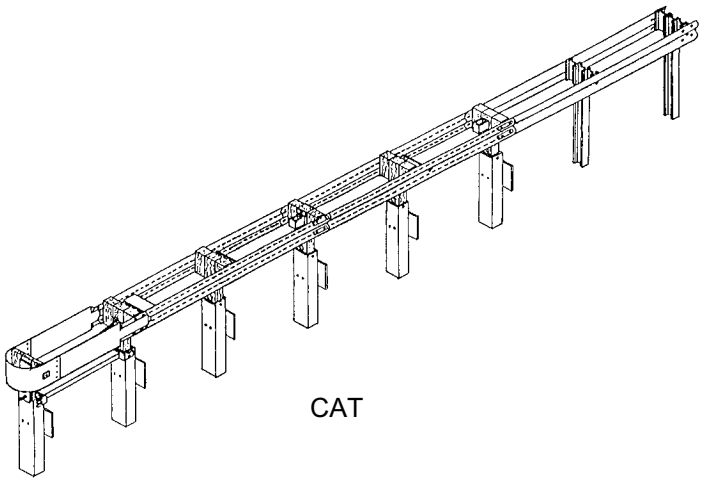
When a transition to connect with a concrete barrier (see Figure 720-5) is required, the transition type and connection must be specified and are included in the cost of the impact attenuator. See Chapter 710 for information on the transitions and connections to be used.

Contractors can be given more flexibility in the selection of work zone (temporary) systems, since long-term maintenance and repair are not a consideration.

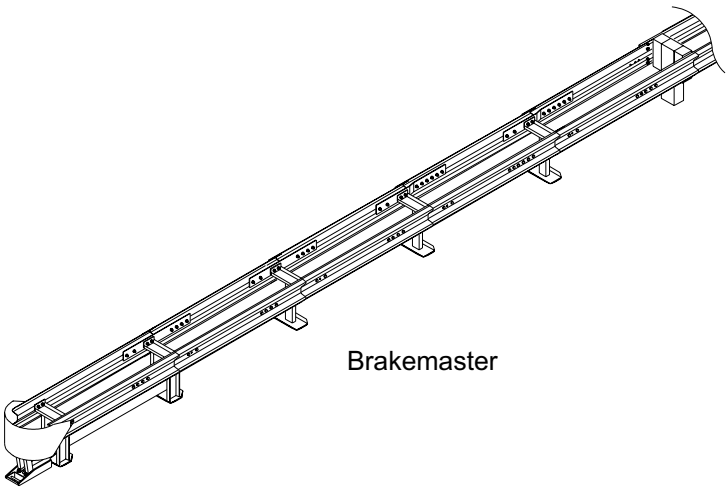
720.04 Documentation

The following documents are to be preserved in the project's design documentation file. See Chapter 330.

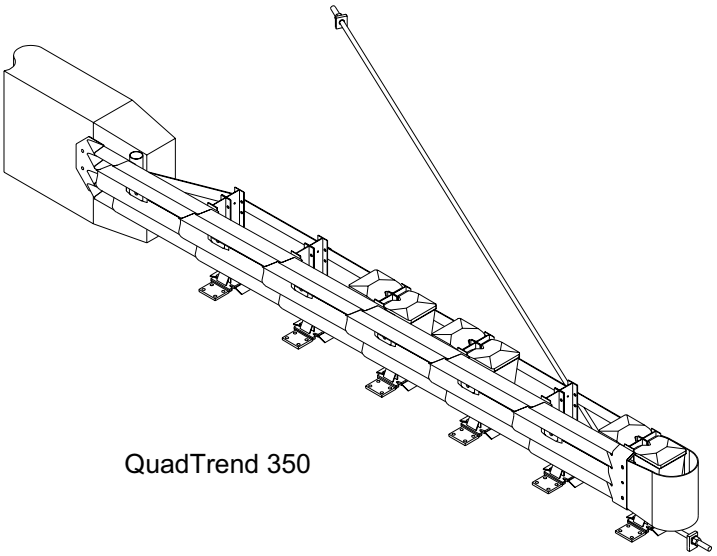
- ☐ Approvals for use of older systems.
- ☐ Documentation of reasons for eliminating attenuator options.
- ☐ Approvals of public interest findings regarding sole source proprietary systems.



CAT



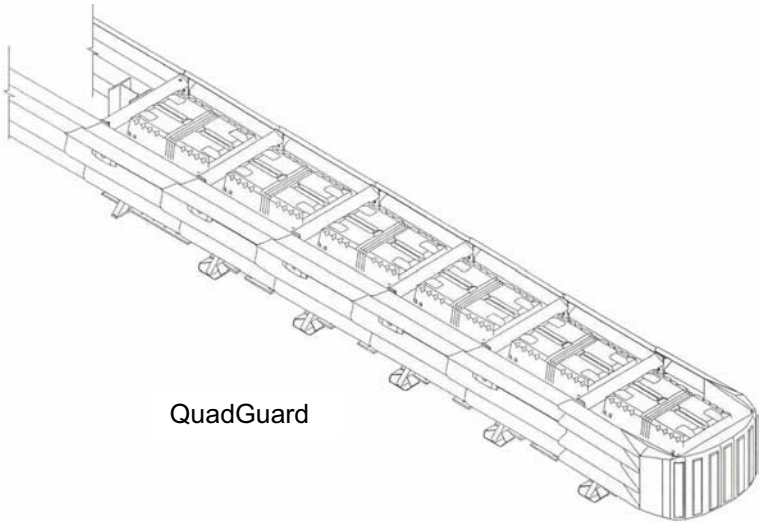
Brakemaster



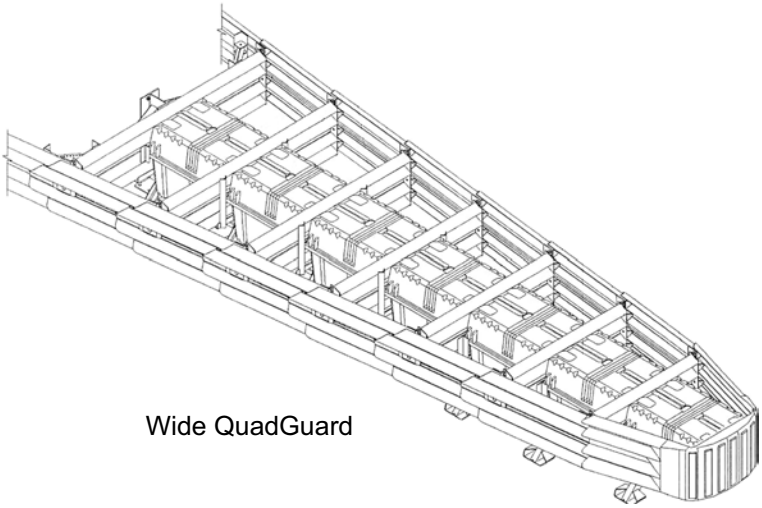
QuadTrend 350

Impact Attenuator Systems — Permanent Installations

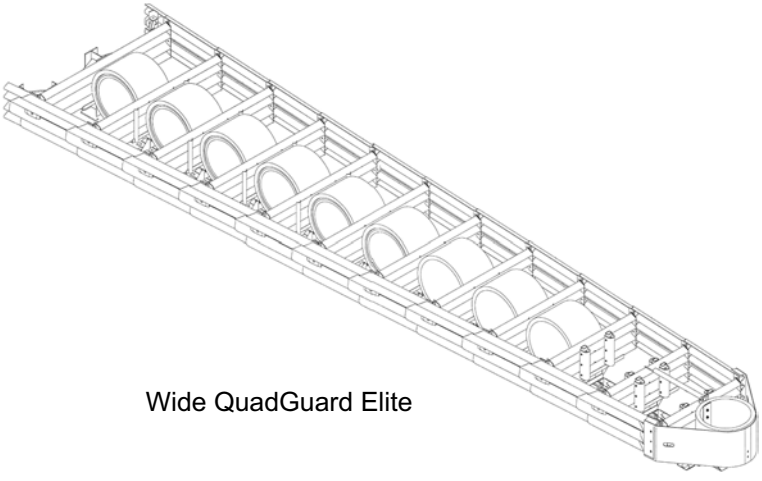
Figure 720-2a



QuadGuard



Wide QuadGuard

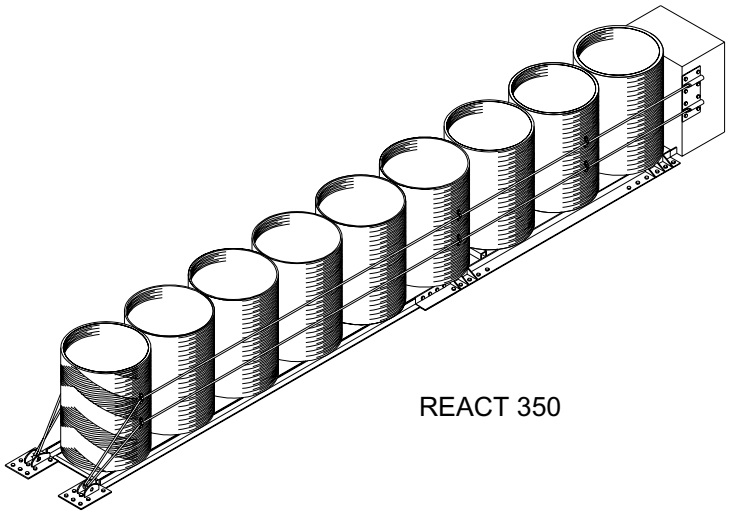


Wide QuadGuard Elite

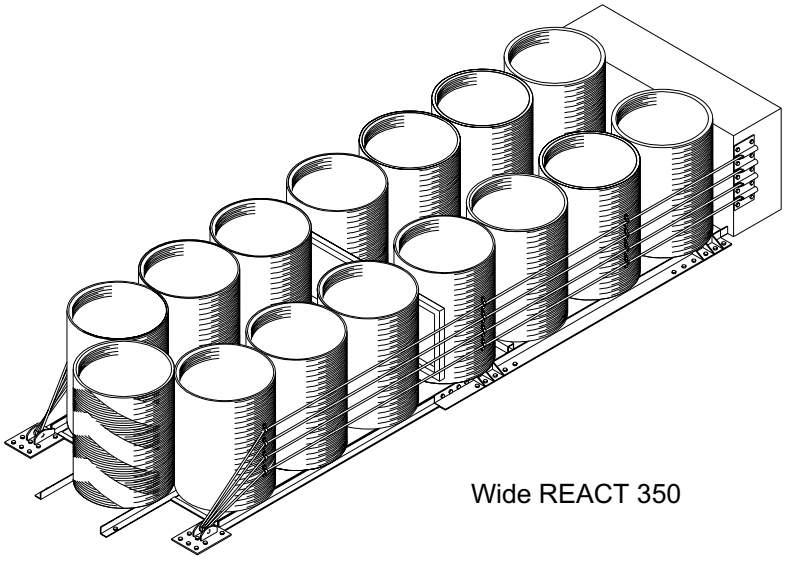
Impact Attenuator Systems — Permanent Installations
Figure 720-2b

TAU-II

Impact Attenuator Systems — Permanent Installations
Figure 720-2c



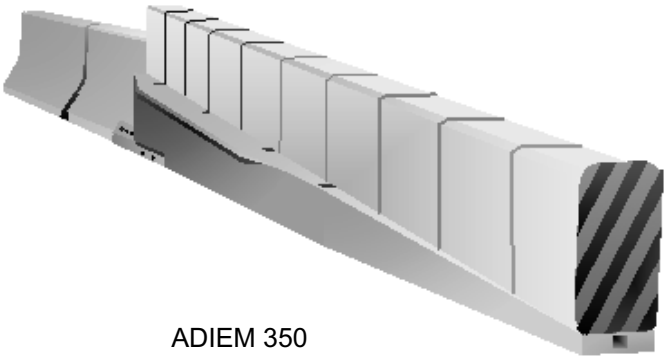
REACT 350



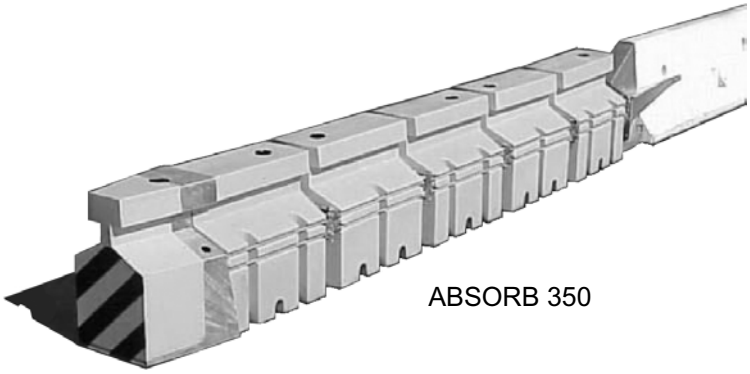
Wide REACT 350

Inertial Barrier

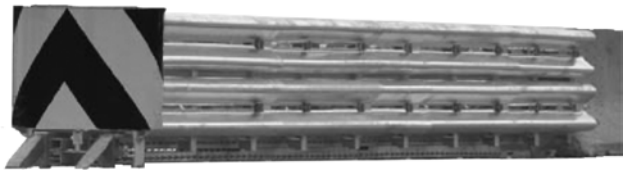
Impact Attenuator Systems — Permanent Installations
Figure 720-2d



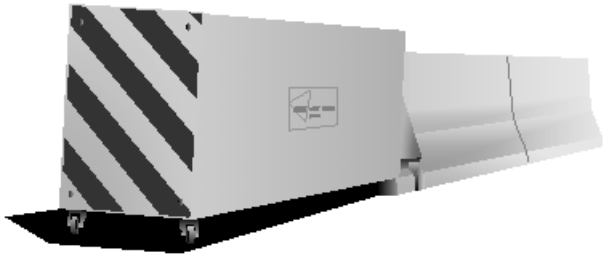
ADIEM 350



ABSORB 350

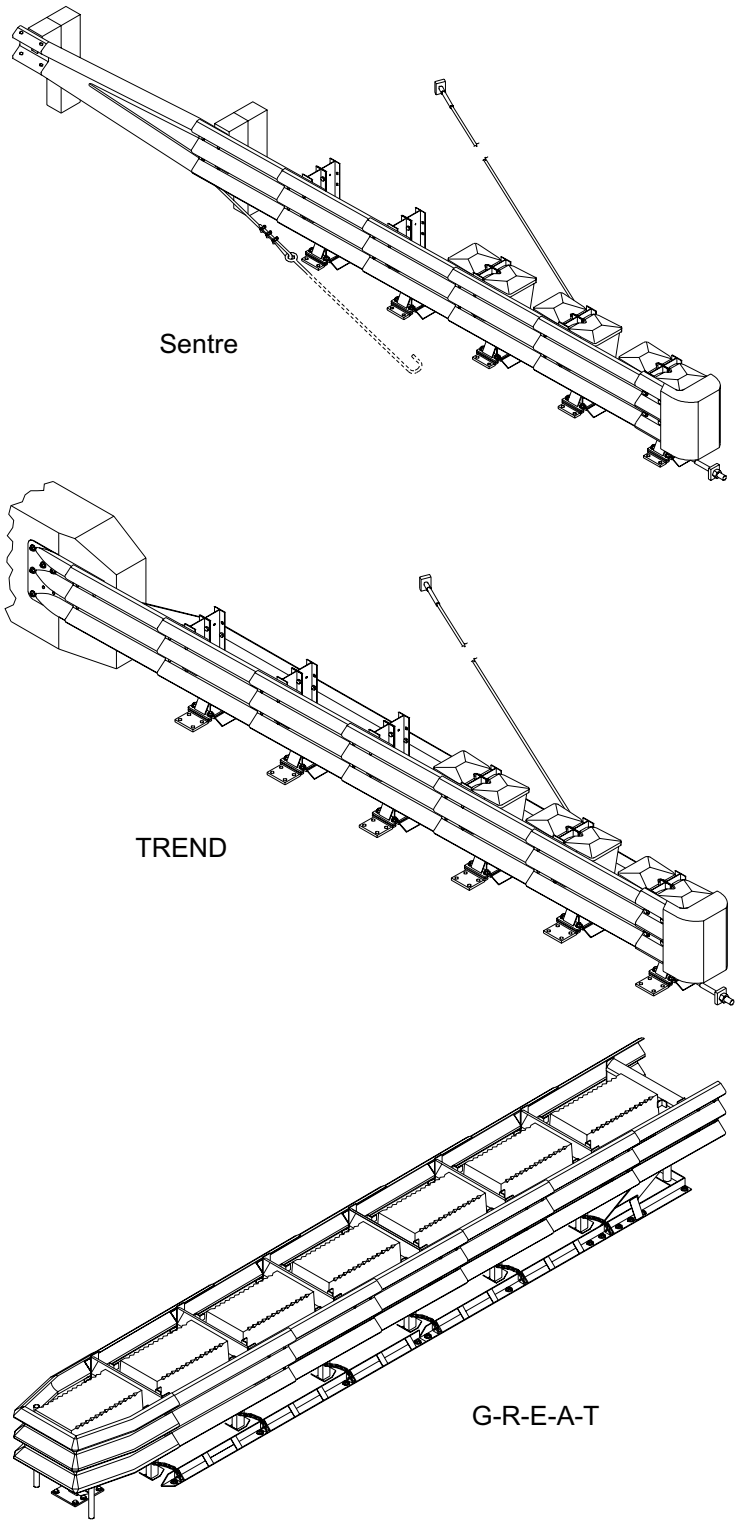


TRACC

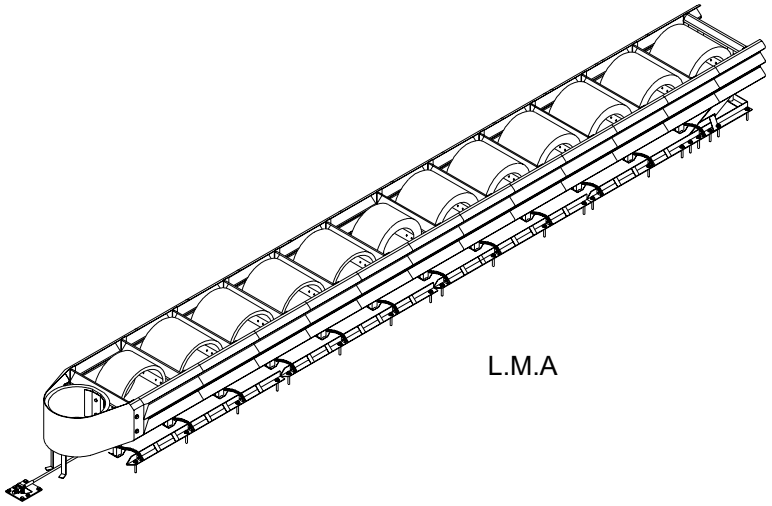


N-E-A-T

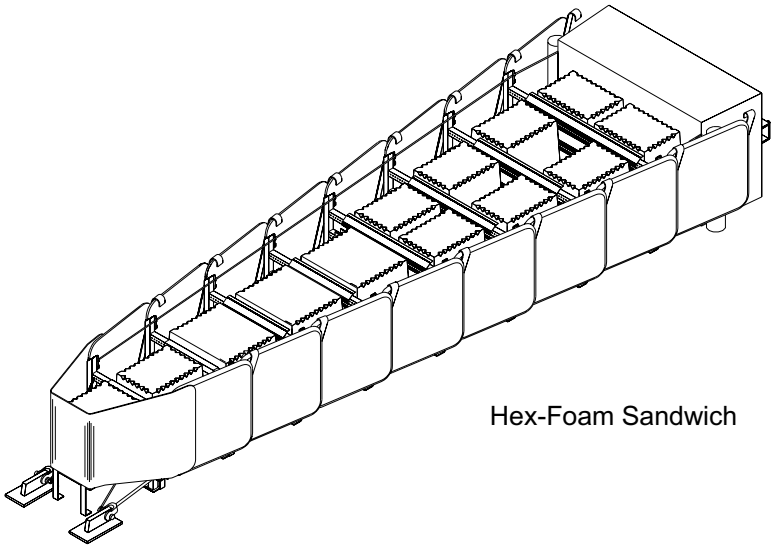
Impact Attenuator Systems — Work Zone Installations
Figure 720-3



Impact Attenuator Systems — Older Systems
Figure 720-4a



L.M.A



Hex-Foam Sandwich

Impact Attenuator Systems — Older Systems
Figure 720-4b

Impact Attenuator Systems

(All dimensions are in feet)

System	(P) permanent, (T) temporary, (B) both	Width	Length	Transition to Rigid System Required	Distance Beyond Length of Need	Initial Cost Category[1]
CAT[2]	P	2	31.25	Y	18.8	A
Brakemaster[2]	P	2	31.5	Y	15.8	A
QuadTrend - 350[6]	P	2	20.7	N	10.5	A
TAU-II	P	2.9	14 -26[4]	N	3	B[5]
QuadGuard	B	2, 2.5, 3, 5.75, 7.5	12 - 30[4]	N	3.3	C[5]
QuadGuard Elite	B	2, 2.5, 3, 5.75, 7.5	35.5	N	3.3	D
REACT 350	B	3	15.25 - 36.25[4]	N	4.3	C[5]
Wide REACT 350	B	6-9	23.25	N	4.3	D[5]
Inertial Barriers	B	7	17 - 30[4]	N	[3]	A[5]
ABSORB 350[9]	T	2	17.7/27	Y	17.7/27[3]	A[5]
ADIEM 350[7]	T	2	30	N	14.1	B
QuadGuard cz	T	2, 2.5, 3, 5.75, 7.5	22	N	3.3	C[5]
N-E-A-T[8]	T	1.9	9.7	N	[3]	C[5]
TRACC	T	2.6	21	N	8	B

1) A ($5,000 to $10,000); B ($10,000 to $15,000); C ($15,000 to $25,000); D ($25,000 to $40,000). These are rough initial cost estimates - verify actual costs through manufacturers/suppliers. Some products are priced very close to the margin between cost categories.
2) Generally for use with double-sided beam guardrail. Use as an end treatment for concrete barrier requires a transition.
3) The N-E-A-T, inertial barriers, and ABSORB 350 may only be used beyond the required length of need.
4) See Figure 720-1 for sizes or configuration type.
5) The length of the QuadGuard, REACT 350, TAU-II, ABSORB 350, and inertial barriers varies since their designs are dependent upon speed. For a typical 60 mph design: the QuadGuard = 21 ft, the REACT 350 = 31 ft, the ABSORB 350 = 27 ft, the TAU II = 26 ft, and the inertial barrier = 30 ft. Costs indicated are for a typical 60 mph design. (except N-E-A-T)
6) Generally for use at the ends of bridges where installation of a beam guardrail transition and terminal is not feasible.
7) Generally for use with concrete barrier. Other uses may require a special transition design.
8) Use limited to highways with posted speeds of 45 mph or less.
9) The ABSORB 350 was primarily intended for the Quickchange Moveable Barrier (QMB) but may be used with other temporary barrier if beyond the length of need.

Impact Attenuator Comparison

Figure 720-5